# Quarterly Progress Report #5

For the project entitled:

## Field Evaluation of the Performance of Three Concrete Bridge Decks on Montana Route 243

*Reporting Period: January 1, 2003 – March 31, 2003*
(*Quarter 3, State Fiscal Year 2003*)

**Summary of Expenditures**

The table below summarizes the expenditures on this project through March 31, 2003. Expenditures during this quarter were $41,265.37, with total expenditures through March 31, 2003 equaling $141,465.84.

| Budget Category | Spent through 12/31/02 | Spent This Quarter | Total Spent |
|---|---|---|---|
| Salaries | $32,714.85 | $16,254.84 | $48,969.69 |
| Benefits | $4,716.72 | $3,118.08 | $7,834.80 |
| In-State Travel | $393.25 | $271.94 | $665.19 |
| Expendable Supplies | $1,542.49 | $1,268.05 | $2,810.54 |
| Tuition | $14,755.25 | $6,365.25 | $21,120.50 |
| Reporting | $0.00 | | $0.00 |
| MDT Direct Costs | $54,122.56 | $27,278.16 | $81,400.72 |
| Overhead | $7,873.53 | $4,182.59 | $12,056.12 |
| MDT Share | $61,996.09 | $31,460.75 | $93,456.84 |
| WTI Share (Equipment and Out-of-State Travel) | $38,195.38 | $9,804.62 | $48,000.00 |
| **Total** | **$100,191.47** | **$41,265.37** | **$141,456.84** |

**Task A: Project Management**

Eli Cuelho and Jerry Stephens of WTI/MSU attended the pre-decking meeting in Saco on January 16th. Items discussed at the meeting generally focused on how planned research efforts will be integrated into the conventional construction activities at the site. Minutes from this meeting were prepared and sent to Craig Abernathy on February 10th.

The bridge construction effort is reported to be on schedule. WTI has communicated with Sletten to finalize the details regarding the delivery of the instrumented rebar to the project site. The current plan is to have the rebar delivered by truck to the construction site on April 21st. Eli Cuelho of WTI will be present when the rebar is delivered. Once delivered, installation of the instrumented pieces will begin. He will remain on site to ensure proper installation of the bars and to begin routing lead wires.

Action Items for next quarter:

- Coordinate with various construction activities to ensure smooth integration of research components
- Monitor installation of instrumented reinforcing steel

**Task B: Conduct Literature Review**

The primary literature review for this project has been completed. Nonetheless, the time frame for this project is quite long, so information will continue to be collected throughout its duration.

Action Items for next quarter:

- Continue collecting relevant literature
- Write up the literature review for use in future documentation and in the instrumentation plan

**Task C: Develop Instrumentation Plan and Assemble Data Acquisition System**

***Determine Gage Locations***

A second draft of the report documenting the process used to select the gage locations in each deck was completed. It is anticipated that the final draft of this report will be completed and available the first week in May.

Action Items for Next Quarter:

- Finalize and send draft instrumentation plan to MDT

***Purchase and Assemble Weather Station***

The website for disseminating the real-time weather data was completed (http://wtigis.coe.montana.edu/saco/Saco_Current.htm). Its features include:

- 15 minute updates of temperature, wind speed and direction, relative humidity, dew point, and barometric pressure;
- a collection of the past 24 hours of data updated every 15 minutes;
- 1 month of daily averages;
- 1 month of daily maximums;
- 1 month of daily minimums; and
- various pictures associated with the project.

Links contained on the website above provide access to the information outlined in the bulleted list above. Development of the database that will be used to store and organize data collected from the weather station continued.

Action Items for Next Quarter:

- Finalize database to organize and store weather data

***Purchase and Assemble Bridge Monitoring Data Acquisition System***

Substantial preparations have been made toward completing the data acquisition system this quarter. In general, work has focused on:

- designing and purchasing power and communications hardware,
- performing lab tests to verify gage outputs,
- designing and building data acquisition circuitry, and
- programming the data logger.

Design of the solar power system was completed. The system was optimized for the solar radiation conditions in northern Montana using data from a solar station located in Glasgow, Montana. The solar panel will be installed on a 14-foot pole located near the bridge (Figure 1). It will be connected to the battery, which will be located near the data acquisition system, using a buried cable. Power from the solar panel will be regulated and distributed to the data acquisition system using a controller/regulator (Figure 2). The battery has approximately two weeks of life in the event the solar panel malfunctions or is damaged. All power components will be enclosed in a steel box under the bridge to protect them from environmental damage and vandalism.

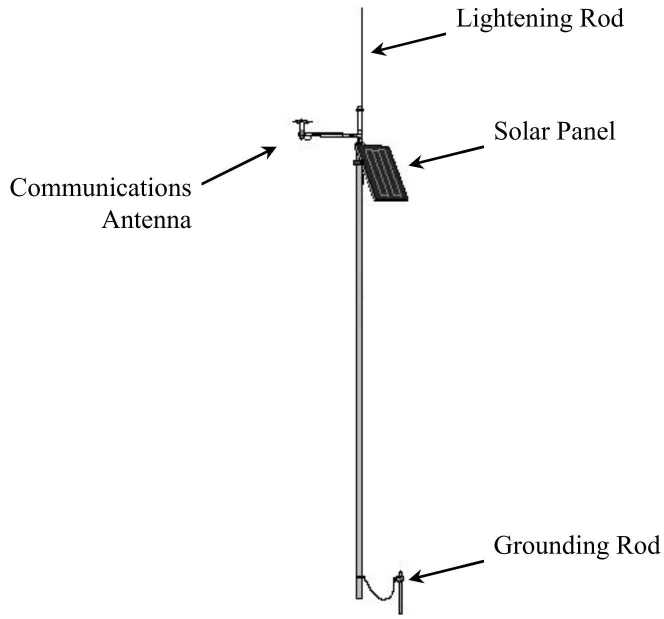


**Figure 1: General Power and Communications Tower Design**

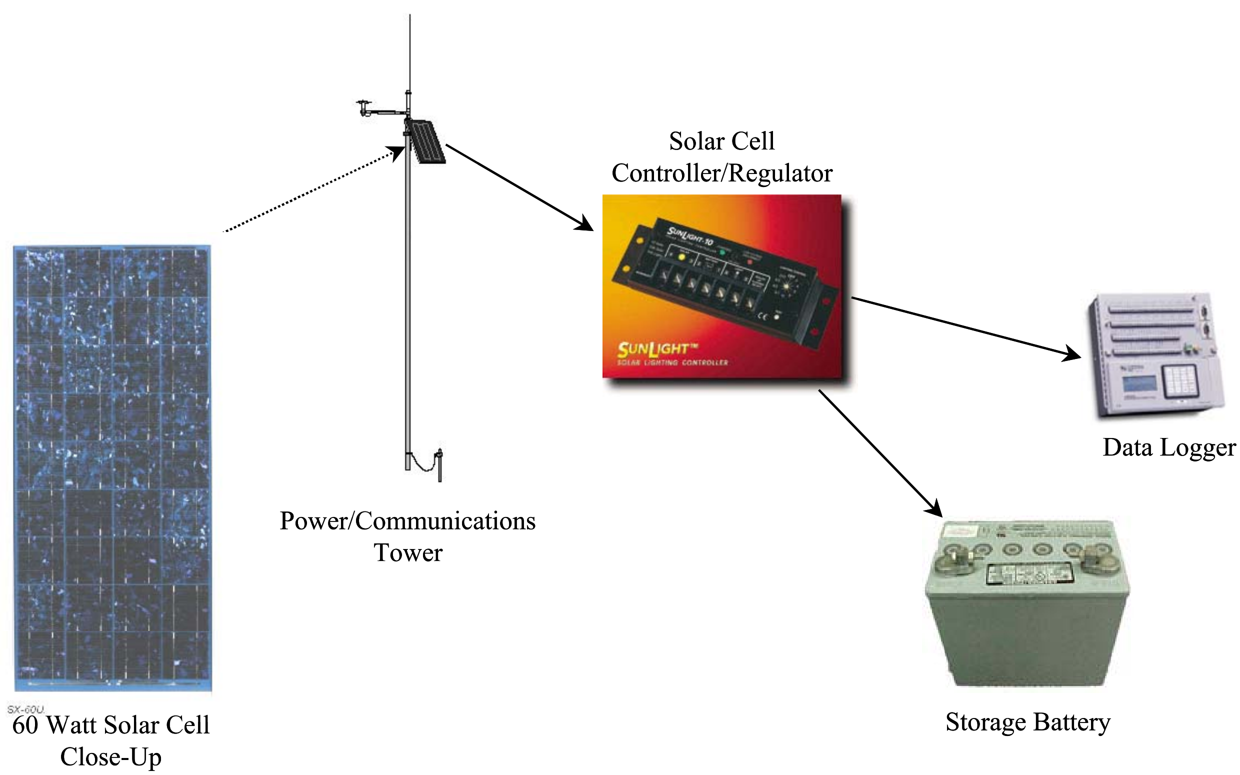


**Figure 2: Power Hardware Setup**

Originally, land-based telephone connections were going to be utilized to transfer data from the data acquisition systems located under the bridge deck to a database at WTI. A spread spectrum radio was chosen over a land-based telephone line due to increased convenience and lower overall cost. Each antenna will communicate at 900 MHz to a single receiving antenna collocated with the weather station at the Saco Public School. Information will be transferred from the school to WTI via the Internet. The transmitting antenna will be attached to the 14-foot pole with the solar power system. In addition, a lightning rod will be connected to this pole to provide lightning protection. Figure 3 shows the power and communications plan.

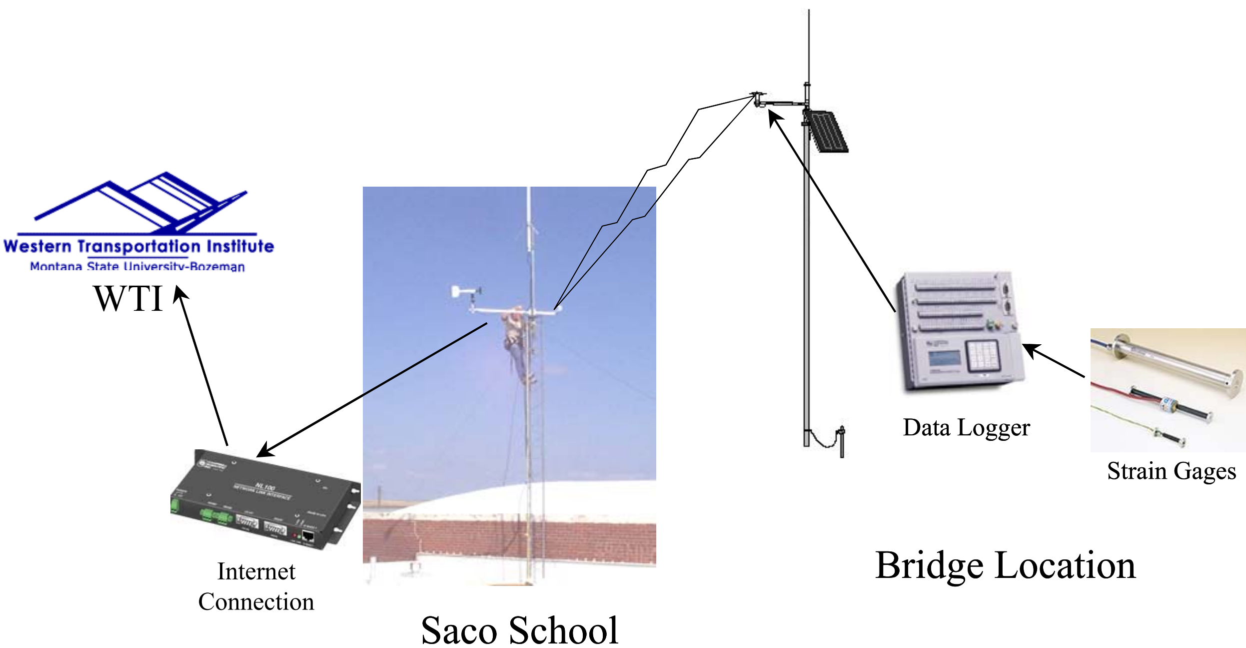


**Figure 3: Power and Communications Plan**

Last quarter, a concrete test beam was designed and fabricated to evaluate the durability of the gage installations on the reinforcing steel, and to help refine the strain gage circuitry. All of the strain gages survived construction, confirming the durability of the installation procedure. Further testing continued this quarter to verify the outputs of the strain gage circuitry. Items of concern when designing the circuitry included the accuracy of the output as compared to theoretical calculations, electronic stability over time and at various temperatures, and noise abatement. Initial tests found that the gage output matched the theoretical predictions reasonably well, and that noise was generally controllable using various circuit and programming modifications. However, it was difficult to assess electronic stability for long periods of time and at various temperatures due to the cumbersome nature of the concrete beam. Additionally, differences between the single-ended and differential circuits needed to be further understood.

To evaluate these items of concern, tests were conducted at lower temperatures for sustained periods of time using the strain gages that were bonded to the longitudinal reinforcement. Due to difficulties in interpreting the data from these tests, the results were somewhat inconclusive. A new specimen was made for evaluation purpose that consisted simply of a small piece of rebar with bonded strain gages that could be used in a controlled laboratory setting.

Gages were installed at two different locations along the length of the bar to allow simultaneous monitoring using varying circuit configurations. Electrical stability, circuit configuration, data precision, and data accuracy were more easily investigated using the test bar. An apparatus was built to hang a weight from the test bar for extended periods of time. An initial test conducted for one week helped select the final circuitry configuration. The test bar will be used in the coming quarter to conduct more extensive temperature and time-dependent tests in conjunction with the complete data acquisition system.

Each bridge will have 42 strain gage locations – 35 bonded to the reinforcement and 7 embedded in the concrete. The circuitry used in conjunction with these strain gages will consist of seven identical circuit boards, each of which will service six bonded strain gages and one embedded strain gage. These boards are called “daughterboards” since they relay information to the “motherboard.” As such, these seven boards will be connected to the data logger and a peripheral multiplexer via the motherboard. This connection scheme will add flexibility to route or reroute selected strain gages to the data logger without having to rewire the entire system. A prototype board was created using this design and will be tested before further production takes place. All circuitry will be finalized and built next quarter. The recently acquired environmentally sealed enclosures will be fitted with these various components.

Drafts of the computer programs needed to run the data acquisition equipment have been created using software supplied by Campbell Scientific. A considerable amount of work remains to develop a program that will provide flexibility, accuracy and dependability for the large quantity and variety of data that is expected. A full test of the program’s capabilities, including a full power and communications test, will be conducted before the system is assembled at the bridges in Saco. The final program will be ready for operation by the time the bridge decks are poured in late May – early June.

<u>Action Items for Next Quarter</u>

- Set up and test solar power and communications equipment in the lab and in the field
- Finalize the design of the 14-foot pole to accommodate the solar panel, lightning rod and communications antenna and erect it at the site
- Test circuitry, gages, and computer program using the instrumented test bar
- Complete fabrication of circuitry and assemble components in the environmentally sealed enclosures
- Test and finalize computer program for the data acquisition system

**Task D: Install Instrumentation and Compile As-Built Documentation**

***Instrumentation Installation***

Installation of strain gages to the reinforcing steel began using the tools and procedures from Vishay – Micromeasurements Group. Bonding resistance strain gages to the epoxy-coated reinforcement followed several steps. The process included:

1. locating and marking the desired location,
2. grinding away the epoxy coating and steel ribs to make a smooth bonding surface,
3. cleaning and neutralizing the area,
4. gluing the gage onto the bar,
5. soldering the lead wires to the gage,
6. cleaning the area of any contaminants, and
7. covering the area with a coating to provide environmental and mechanical protection.

Completed bars were bundled securely together and stored indoors on the Montana State University campus. Most of the bonded strain gages were installed this quarter, and the remainder will be installed next quarter before all the instrumented bars are ready to be shipped to the construction site. Shipping is anticipated to occur on or before the $21^{st}$ of April, so as not to delay bridge construction. Installation may begin immediately upon delivery.

The vibrating wire strain gages to be embedded in the bridge deck for long term monitoring effort were purchased from Geokon and the embedded strain gages were purchased from Vishay – Micromeasurements Group. The vibrating wire and embedded strain gages will be installed and lead wires will be routed through exit ports located on the bottom of the deck once the reinforcing steel mesh for a particular bridge has been completed.

Precise locations of each instrument location will be documented after they are installed but before the deck concrete is placed. Monitoring of all the sensors will begin prior to the decks being cast and continue through concrete placement and curing.

***Materials Testing***

Test specimens will be collected from a representative portion of the concrete used to cast the instrumented section of each deck. All supplies necessary for this task (notably, cylinder and beam molds) will be purchased and shipped to the bridge site. The specific point and time at which the concrete is sampled from each deck will be determined in conjunction with the contractor to ensure that the sampled concrete is indeed from the desired area of the deck. Protocols will be worked out for storing, transporting, and curing the test specimens. The feasibility of casting some ring test specimens will be investigated. These specimens, with inside diameter of 300 mm, a 75 mm wall thickness, and a 150 mm height, are increasingly being used to evaluate the cracking behavior/potential of plain concrete. MDT will be contacted regarding material property information for the reinforcing steel used in the decks.

Action Items for Next Quarter

- Finish attaching bonded strain gages to reinforcing steel
- Deliver instrumented reinforcing steel to construction site
- Install instrumented reinforcement into reinforcing mats within the bridge deck, in their specified locations
- Install vibrating wire strain gages and embedded strain gages
- Route lead wires through the bottom of the bridge deck forms
- Connect transducer lead wires to the data acquisition system
- Document as-built gage locations prior to deck casting
- Monitor sensor responses during and after bridge deck construction
- Collect concrete test specimens as decks are cast and store them
- Collect material properties of the reinforcing steel from MDT
- Permanently route instrumentation lead wires through PVC plumbing to the central data acquisition system once deck forms are removed

**Task E: Live Load Testing**

The specific tests to be conducted on each bridge for the initial set of live load tests will be determined during the next reporting period. A 3-axle dump truck loaded at its maximum capacity will be used as the test vehicle. Target axle weights for this vehicle are 12,000 to 16,000 lbs on the steer axle and 34,000 lbs on the tandem axle. The actual wheel loads of the test vehicle will be measured using a portable scale. Both the static and dynamic response of each bridge will be measured under this vehicle load. "Static" data will be collected by slowly driving across each bridge along several trajectories at different transverse positions (i.e., wheel lines straddling exterior stringer, wheel line over exterior stringer, wheel lines straddling interior stringer, etc.). Vehicle position will be established using grid lines marked on the surface of the decks. Dynamic data will be collected during these tests. The tests will be conducted at three speeds: 1) slow-rolling (essentially static) test, 2) "moderate" speed tests representing approximately half of the speed limit, and 3) "high" speed tests conducted at the specified speed limit. Actual speeds at which these tests will be conducted will depend on the characteristics of the bridge approaches, the capabilities of the test truck, and the speed limit.

Additional information on the general linearity of the bridges' response will be obtained by testing each bridge at a second load level. These tests will be conducted using an empty dump truck. While it would be convenient to have a second truck (of similar configuration to the first truck) for these tests, they can be conducted by unloading the first truck. A further advantage of having two trucks available is that the deck response can also be measured for the case of multiple vehicles on the bridge simultaneously traveling in opposite directions.

During all tests, transducer responses will be recorded as a function of truck position along the bridge. Select gages will be viewed in real-time during the tests. These gages will be used to ensure that the instrumentation is functioning properly. Ideally, all live load tests will be conducted under similar weather/temperature conditions, so that the initial strain conditions in each deck are generated by a common set of environmental conditions.

Action Items for Next Quarter:

- Determine protocols for the live load tests
- Coordinate live load test preparations with Sletten Construction and MDT

**Task F: Long-Term Monitoring**

***Monitoring Global Bridge Movements through Surveying***

Global bridge movements will be monitored by measuring relative changes in the elevation and the horizontal position of various points on the surface of each deck. Initial measurements will be made approximately 28 days after the construction of each bridge. Elevation measurements will be made at 36 locations on each deck, namely, over the abutments, interior bents, and diaphragms of each bridge at the location of each stringer (28 measurements), and between stringers in the instrumented areas of the decks (8 locations). In the horizontal plane, 14 measurements will be made, namely, over the abutments, interior bents, and diaphragms of each bridge at the location of the exterior stringers. Permanent reference points will be installed in the decks at each of these 14 locations. Elevation and position measurements also will be made at two locations on each abutment. All measurements will be made with conventional surveying equipment, with the intention of locating each point to the nearest millimeter.

Action Items for Next Quarter:

- Make preparations for monitoring global bridge movements
- Purchase necessary surveying equipment

***Corrosion Testing***

Preparations will be made for conducting baseline corrosion tests on each deck. Prior to construction, leads will be connected to two transverse and two longitudinal bars in each deck for conducting half-cell potential tests. The lead wires will exit the underside of the bridge deck so they can be accessed post-construction when these tests are conducted. Half-cell potential readings will be made at regular intervals along the length of each bar. Preparations will also be made for making benchmark chloride ion and carbonation tests.

Action Items for Next Quarter:

- Install lead wires to specified bars
- Make preparations to conduct these tests after construction

**Task H: Project Reporting**

A draft instrumentation plan has been prepared which includes 1) a complete instrumentation list that indicates the type, location, and expected level of response of each gage, and 2) a thorough description of the specific installation method proposed for each type of gage including the manner in which it will be wired into the data acquisition system. A final draft should be available the first week of May.

Action Items for Next Quarter:

- Quarterly progress report for fourth quarter for state fiscal year 2003